527 Rec'd PCT/PTO 27 APR 2000

FORM PTO-1390 (Modified) (REV 11-98) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER
A31358-PCT USA

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR
09/530308

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/US98/22790	**27 October 1998**	**27 October 1997**

TITLE OF INVENTION
WATERMARKING OF DIGITAL IMAGE DATA

APPLICANT(S) FOR DO/EO/US
CHANG, Shih-Fu and MENG, Jianhao

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ A copy of the International Search Report (PCT/ISA/210).
8. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
9. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
10. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 13 to 20 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☐ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☒ Certificate of Mailing by Express Mail
20. ☒ Other items or information:

Form PCT/RO/101; Forms PCT/IB/301/304/308/332; Forms PCT/IPEA/401/402/408/416; Form PCT/ISA/210/220; a postcard, and a check in the amount of $670.00.

Express Mail No: EJ339572546US
Date of Deposit: 27 April 2000

PCTUS1/REV03

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U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 09/530308	INTERNATIONAL APPLICATION NO. PCT/US98/22790	ATTORNEY'S DOCKET NUMBER A31358-PCT USA

21. The following fees are submitted:.

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

	CALCULATIONS	PTO USE ONLY
☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2) paid to USPTO and International Search Report not prepared by the EPO or JPO **$970.00**		
☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but Internation Search Report prepared by the EPO or JPO **$840.00**		
☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO **$690.00**		
☒ International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$670.00**		
☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) **$96.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =	**$670.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).	**$0.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	5 - 20 =	0	x $18.00	**$0.00**	
Independent claims	1 - 3 =	0	x $78.00	**$0.00**	
Multiple Dependent Claims **(check if applicable).**			☐	**$0.00**	
	TOTAL OF ABOVE CALCULATIONS =			**$670.00**	
Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28) **(check if applicable).** ☐				**$0.00**	
	SUBTOTAL =			**$670.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). +				**$0.00**	
	TOTAL NATIONAL FEE =			**$670.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).** ☐				**$0.00**	
	TOTAL FEES ENCLOSED =			**$670.00**	
				Amount to be: refunded	$
				charged	$

☒ A check in the amount of **$670.00** to cover the above fees is enclosed.

☐ Please charge my Deposit Account No. in the amount of to cover the above fees. A duplicate copy of this sheet is enclosed.

☒ The Commissioner is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. **02-4377** A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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New York, NY 10112-0228

Henry Tang
SIGNATURE

Henry Tang
NAME

29,705
REGISTRATION NUMBER

27 April 2000
DATE

Attorney's Docket No. A31358-PCT-USA
Baker Botts L.L.P.

Applicant or Patentee: Shih-Fu Chang et al.
Serial or Patent No.: 09/530,308 Filed or Issued: April 27, 2000
For: WATERMARKING OF DIGITAL IMAGE DATA

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) and 1.27(d)) - NONPROFIT ORGANIZATION

I hereby declare that I am an official empowered to act on behalf of the nonprofit organization identified below:

NAME OF ORGANIZATION THE TRUSTEES OF COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

ADDRESS OF ORGANIZATION 116th St. and Broadway, New York, New York 10027

TYPE OF ORGANIZATION

[X] UNIVERSITY OR OTHER INSTITUTION OF HIGHER EDUCATION
[ ] TAX EXEMPT UNDER INTERNAL REVENUE SERVICE CODE]26 USC 501(a) and 501(c)(3))
[ ] NONPROFIT SCIENTIFIC OR EDUCATIONAL UNDER STATUTE OF STATE OF THE UNITED STATES OF AMERICA
(NAME OF STATE __)
(CITATION OF STATUTE __)
[ ] WOULD QUALIFY AS TAX EXEMPT UNDER INTERNAL REVENUE SERVICE CODE (26 USC 501(a) and 501(c)(3)) IF LOCATED IN THE UNITED STATES OF AMERICA
[ ] WOULD QUALIFY AS NONPROFIT SCIENTIFIC OR EDUCATIONAL UNDER STATUTE OF STATE OF THE UNITED STATES OF AMERICA IF LOCATED IN THE UNITED STATES OF AMERICA
(NAME OF STATE __)
(CITATION OF STATUTE __)

I hereby declare that the nonprofit organization identified above qualifies as a nonprofit organization as defined in 37 CFR 1.9(e) for purposes of paying reduced fees under Section 41(a) and (b) of Title 35, United States Code with regard to the invention entitled WATERMARKING OF DIGITAL IMAGE DATA by inventor(s) Shih-Fu Chang and Jianhao Meng described in

[ ] the specification filed herewith
[X] Application Serial No. 09/530,308, filed April 27, 2000.
[ ] Patent No. __, issued __.

I hereby declare that the rights under contract or law have been conveyed to and remain with the nonprofit organization with regard to the above identified invention.

If the rights held by the nonprofit organization are not exclusive, each individual, concern or organization having rights to the invention is listed below* and no rights to the invention are held by any person, other than the inventor, who could not qualify as a small business concern under 37 CFR 1.9(c) or by any concern which would not qualify as a

NY02.281145.1

Baker Botts L.L.P.

Attorney's Docket No. A31358-PCT-USA

small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e). *Note: Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)

NAME __________
ADDRESS __________
[ ] INDIVIDUAL [ ] SMALL BUSINESS CONCERN [ ] NONPROFIT ORGANIZATION

NAME __________
ADDRESS __________
[ ] INDIVIDUAL [ ] SMALL BUSINESS CONCERN [ ] NONPROFIT ORGANIZATION

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

NAME OF PERSON SIGNING Beth H. Israel

TITLE IN ORGANIZATION Executive Director Office of Projects and Grants

ADDRESS OF PERSON SIGNING 500 West 120th St., New York, NY 10027

SIGNATURE Beth H. Israel DATE Aug 30, 2000

PTO/PCT Rec'd 27 APR 2000
PCT/US98/22790
09/530308

WATERMARKING OF DIGITAL IMAGE DATA

Priority is claimed based on U.S. Provisional Application No. 60/063,509, filed October 27, 1997.

Technical Field

This invention relates to providing digital image data with a watermark, and, more particularly, where the image data are video data.

Background of the Invention

A conventional watermark, on a paper document, may consist of a translucent design which is visible when the document is held to the light. Or, more generally, a watermark may be viewed under certain lighting conditions or at certain viewing angles. Such watermarks, which are difficult to forge, can be included for the sake of authentication of documents such as bank notes, checks and stock certificates, for example.

In digital video technology, watermarks are being used to betoken certain proprietary rights such as a copyright, for example. Here, the watermark is a visible or invisible pattern which is superposed on an image, and which is not readily removable without leaving evidence of tampering. Resistance to tampering is called "robustness".

One robust way of including a visible watermark in a digitized image is described by Braudaway et al., "Protecting Publically Available Images with a Visible Image Watermark", IBM Research Division, T. J. Watson Research Center, Technical Report 96A000248. A luminance level, ΔL, is selected for the strength of the watermark, and the luminance of each individual pixel of the image is modified by ΔL and a nonlinear function. For increased security, the level ΔL is randomized over all

the pixels in the image.

Summary of the Invention

When images are transmitted as transformed by discrete cosine transformation (DCT) for compression, with or without motion compensation, it is advantageous to include a watermark *after* transformation. To this end, (i) a DCT watermark is generated for optimal visibility based on the original image data, and (ii) the generated watermark is superposed on the transformed data.

Brief Description of the Drawing

Fig. 1 is an illustration for motion-compensated discrete cosine transformation (MC-DCT).

Fig. 2a is a watermark mask.

Fig. 2b is an original image.

Fig. 2c is a superposition of the original image and the watermark mask.

Fig. 3 is a flow diagram of initial processing.

Fig. 4 is a flow diagram of watermark superposition processing.

Fig. 5 is a flow diagram of scaling for a region.

Detailed Description

A Mask Generation Module generates a DCT watermark mask based on the original video content. A Motion Compensation Module efficiently inserts the watermark in the DCT domain and outputs a valid video bitstream at specified bitrate. The following description applies specifically to image data in MPEG format.

MPEG video consists of groups of pictures (GOP) as described in document ISO/IEC 13818 - 2 Committee Draft (MPEG-2). Each GOP starts with an intra coded "I-frame", followed by a number of forward-referencing "P-frames"

and bidirectionally-referencing "B-frames".

With motion compensation, when a watermark is inserted in an I-frame, the P- and B-frames in the GOP will be changed also. For such correction, the motion compensation on the watermark in an anchor or base frame must be subtracted when the watermark is added to a current frame. For such subtraction, the technique of motion compensation in the DCT domain can be used as described by S. F. Chang et al., "Manipulation and Compositing of MC-DCT Compressed Video", IEEE Journal of Selected Areas in Communications, Special Issue on Intelligent Signal Processing, pp. 1-11, January 1995.

In a video sequence, the image content changes from frame to frame. Thus, to keep a watermark sufficiently visible throughout the video, the watermark must be adapted to the video contents. For example, when an image is complicated or "busy", i.e., when it has many high-frequency components, the watermark should be stronger. For different regions in the same video frame, the watermark should be scaled regionally— thereby enhancing the security against tampering.

(i) <u>Mask Generation Module</u>

In this module, as illustrated by Section (i) of Fig. 4, a watermark mask image is first generated for each GOP, or for the first P-frame after a scene cut. This is based on the fact that video content tends to be consistent within a GOP which is usually about 15 frames or 0.5 second long. But, when there is a scene cut within a GOP, visual content will change significantly, and a new mask is used to adapt to the new visual content. Thus, the watermark mask is superposed on the I-frame, or on the first P-frame after a scene cut.

To generate the mask, as illustrated by Fig. 3, the input watermark image is first converted to a gray scale

image. Only the luminance channel of each image is modified. A transparent color (background color) is chosen. The luminance of all watermark pixels having the transparent color value is set to 0. Optionally, the mask image is randomly shifted in both x- and y-direction. A DCT is applied to obtain the DCT mask of the watermark. The luminance of the mask will be scaled adaptively according to the input image content before adding to the input image.

In the pixel domain, the following formulae have been proposed in the above-referenced report by G. W. Braudaway et al.:

$$w_{nm}' = w_{nm} \cdot y_w/38.667 \cdot (y_{nm}/y_w)^{2/3} \cdot \Delta L \text{ for } y_{nm}/y_w > 0.008856,$$
$$w_{nm}' = w_{nm} \cdot y_w/903.3 \cdot \Delta L \text{ for } y_{nm}/y_w \le 0.008856 \qquad (1)$$

where w_{nm}' is the scaled watermark mask that will be added to the original image, w_{nm} is the non-transparent watermark pixel value at pixel (n,m), y_w is the scene white, y_{nm} is the luminance value of the input image at image coordinates(n,m), and ΔL is the scaling factor which controls the watermark strength.

In accordance with an aspect of the present invention, for scaling in the DCT domain, a stochastic approximation can be used. If y_{nm} and w_{nm} are considered as independent random variables, if y is normalized to the luminance range used in MPEG, namely from [0, 255] to [16, 235], and if $y_w = 235$, then, based on Equations 1, the expected values of w' are

$$E[w'] = 0.1607 \cdot E[w] \cdot E[y^{2/3}] \cdot \Delta L \quad ; \quad y > 17.9319$$
$$E[w'] = 0.2602 \cdot E[w] \cdot \Delta L \quad , \quad y \le 17.9319 \qquad (2)$$

Assuming that y has a normal distribution with mean α and variance β^2, the $E[y^{2/3}]$-term in Equation (2) can be represented as

$$E[y^{2/3}] = \int_{17.9319}^{235} t^{2/3} \cdot \frac{1}{\sqrt{2\pi\beta^2}} e^{-\frac{(t-\alpha)^2}{2\beta^2}} dt = f(\alpha, \beta^2) \tag{3}$$

Thus, $E[y^{2/3}]$ is a function of the mean and the variance of the pixel values.

Equation (2) specifies a relationship between the moments of random variables w, w' and y. This relationship can be extended to the deterministic case to simplify Equation (2), resulting in a linear approximation.

For each 8 by 8 image block, the mean and variance of the block are used to approximate α and β^2 in Equation 3, and the mean α is used to approximate y in deciding which of the formulae to use in Equation 2.

$$\begin{aligned} w'_{ijk} &= 0.1607 \cdot w_{ijk} \cdot f(\alpha, \beta^2) \cdot \Delta L, \quad && \alpha > 17.9319 \\ w'_{ijk} &= 0.2602 \cdot w_{ijk} \cdot \Delta L, && \alpha \le 17.9319 \end{aligned} \tag{4}$$

where, for k = 0, ..., 63, w_{ijk} is the k-th pixel of the i,j-th 8 by 8 block in the watermark image. w'_{ijk} is for the scaled watermark.

Equation 4 approximates the nonlinear function according to Equation 2, by linear functions block by block. The scaled watermark strength depends on the mean and variance of the image block. For each image block, the higher the mean (i.e. the brighter), and the higher the variance (i.e. the more cluttered), the greater the required strength of the watermark for maintaining consistent visibility of the watermark.

The DCT of Equation 4 can be used to obtain the DCT of the watermark mask, which can be inserted in the image in the DCT domain. The mean and variance of the input image can be derived from the DCT coefficients,

$$\alpha = (Y_{DC}/8) \text{ and} \tag{5}$$

$$\beta^2 = Var(y) = \frac{\sum_{l=0}^{63} Y_l^2}{64} - \frac{Y_{DC}^2}{64} = \frac{\sum_{l=1}^{63} Y_l^2}{64} = \frac{(\sum Y_{AC}^2)}{64} \tag{6}$$

where Y_{DC} and Y_{AC} are DC- and AC-DCT coefficients, respectively, of the image block Y.

A new watermark mask is calculated for each I-frame and P-frame, the latter in case of a scene cut. For I-frames, all DCT coefficients are readily accessible after minimal decoding of the MPEG sequence, i.e. inverse variable length coding, inverse run length coding and inverse quantization. For P-frames, since most blocks are in the scene cut, these DCT coefficient can be used immediately. For non-intra coded blocks, the average DC and AC energy obtained from intra coded blocks are substituted.

For further speed-up, the block-based (α_{ij},β_{ij}) pair can be replaced by the average $(\bar{\alpha},\bar{\beta})$ over the whole image or over certain regions. In the following, a multi-region approach is described.

The input image can be separated into many rectangular regions. As illustrated by Fig. 5, for each region an $(\bar{\alpha},\bar{\beta})$ pair is calculated, and the mask is generated accordingly. Typically, the watermark is divided into top and bottom regions. This is suitable for most outdoor views with sky in the upper half of the frame and darker scenery in the lower half, as shown in Fig. 2a, for example. Each region will have a relatively visible watermark using different $(\bar{\alpha},\bar{\beta})$ pairs.

To enhance the security of the watermark further, a randomized location shift can be applied to the watermark image before applying the DCT. This makes removal of the watermark more difficult for attackers who are in possession of the original watermark image, e.g. when a known logo is used for watermark purposes. Sub-pixel randomized location shifting will make it very difficult for the attacker to remove the watermark without leaving some error residue.

The following can be used for shifting. Two random numbers, for x- and y-direction, respectively, are generated and normalized to lie between -1.00 to 1.00. In the spatial domain, sub-pixel shifting is effected by bi-linear interpolation which involves only linear scaling and addition. In the DCT domain, a similar bi-linear operation can be used.

(ii) <u>Motion Compensation Module</u>

Once the DCT blocks of the watermark have been obtained, they are inserted into the DCT frames of the input video in one of three ways, as illustrated by Fig. 4, Section (ii). For I-frame or intra coded blocks in the B- or P-frames, the DCT of the scaled watermark is added directly:

$$E'_{ij} = E_{ij} + W'_{ij} \qquad (7)$$

where E'_{ij} is the i,j-th resulting DCT block, E_{ij} the original DCT block, and W'_{ij} the scaled watermark DCT according to Equation 6.

For blocks with forward motion vector in P-frame, or backward motion vector only in B-frame, the watermark added in the anchor frame has to be removed when adding the current watermark. The resulting DCT error residue is:

$$E'_{ij} = E_{ij} - \mathrm{MCDCT}(W'_F, V_{Fij}) + W'_{ij} \qquad (8)$$

where MCDCT is the motion compensation function in the DCT domain as described in the above-referenced paper by S.-F. Chang et al. W'_F is the watermark DCT used in the forward anchor frame, and V_{Fij} is the forward motion vector, as shown in Fig. 1.

For bidirectional predicted blocks in B-frame, both forward and backward motion compensation has to be

averaged and subtracted when adding the current watermark:

$$E'_{ij} = E_{ij} - (MCDCT(W'_F, V_{Fij}) + MCDCT(W'_B, V_{Bij}))/2 + W'_{ij} \quad (9)$$

where V_F and V_B are forward and backward motion vector, respectively, as shown in Fig. 1.

For skipped blocks, which are the 0-motion, 0-residue error blocks in B- and P-frames, no operations are necessary, as the watermark inserted in the anchor frame will be carried over.

For control of the final bit rate one or more of the following features can be included:

1. Quantize/inverse-quantize the DCT coefficients of the watermark so that most high-frequency coefficients will become zero. The result is a coarser watermark, using fewer bits.

2. Cut off high-frequency coefficients. The effect is similar to low-pass filtering in the pixel domain. There results a smoother watermark with more rounded edges.

3. Motion vector selection, setting the motion vector of a micro-block in P-frame to 0 when the error residue from using motion compensation of this motion vector is larger than without its use.

If the motion vector is used, the residual error is

$$E'_{ij} = E_{ij} - MCDCT(w'_F, V_{Fij}) + w'_{ij};$$

otherwise set $V_{Fij} = 0$.

$$E''_{ij} = E_{ij} - MCDCT(I_F, V_{Fij}) + w'_{ij}$$

where I_F is the DCT of anchor frame.

If $|E''_{ij}| < |E'_{ij}|$, set $V_{Fij} = 0$.

Figs. 2a, 2b and 2c illustrate the use of the adaptive watermarking techniques. Fig. 2a shows the original watermark mask. While a binary version is shown here, the algorithm is capable of handling gray scale with any specified transparent color. Fig. 2b shows an

original image. Fig. 2c shows the new watermarked image.

The watermarking algorithm was tested on a HP J210 workstation, achieving a rate of 6 frames/second. Most of the computational effort went into the MC-DCT operations. If all possible MC-DCT blocks were precomputed, real time performance would be possible. This would require 12 megabytes of memory for 352x240 image size.

In accordance with an aspect of the invention, preferred watermarks offer robustness in that they are not easily defeated or removed by tampering. For example, if a watermark is inserted in MPEG video by the method described above, it would be necessary to recover the watermark mask, estimate the embedding locations by extensive sub-pixel block matching, and then estimate the $(\bar{\alpha},\beta)$ factors for each watermark region. In experiments, there always remained noticeable traces in the tampered video, which can be used to reject false claims of ownership and to deter piracy.

For robustness, a watermark should not be binary, but should have texture which is similar to that of the scene on which it is placed. This can be accomplished by arbitrarily choosing an I-frame from the scene, decoding it by inverse DCT transform to obtain pixel values, and masking out the watermark from the decoded video frame.

When there is camera motion such as panning and zooming in a video sequence, an inserted watermark may be defeated by applying video mosaicing, i.e. by assembling a large image from small portions of multiple image frames. The watermark then can be filtered out as outlier. However, this technique will fail when there are actually moving objects in the foreground, as the watermark will be embedded in the moving foreground objects as well. As a countermeasure in accordance with a further embodiment of the invention, a watermark can be used which appears static relative to over-all or background motion. Such a

camera motion using a 2-D affine model, and then translating and scaling the watermark using the estimated camera motion. The affine model can be described as follows:

The motion vectors in MPEG are usually generated by block matching: finding a block in the reference frame so that the mean square error is minimized. Although the motion vectors do not represent the true optical flow, it is still good in most cases to estimate the camera parameters in sequences that do not contain large dark or uniform regions.

When the distance between the object/background and the camera is large, it is usually sufficient to use a 6 parameter affine transform to describe the global motion of the current frame,

$$\begin{bmatrix} u \\ v \end{bmatrix} = \begin{bmatrix} 1 & x & y & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & x & y \end{bmatrix} \cdot \begin{bmatrix} a_1 & a_2 & a_3 & a_4 & a_5 & a_6 \end{bmatrix}^T$$

where (x,y) is the coordinate of a macroblock in the current frame, $\begin{bmatrix} u & v \end{bmatrix}^T$ is the motion vector associated with that macroblock, $\begin{bmatrix} a_1 & a_2 & a_3 & a_4 & a_5 & a_6 \end{bmatrix}^T$ is the affine transform vector. We denote U for $\begin{bmatrix} u & v \end{bmatrix}^T$, X for $\begin{bmatrix} 1 & x & y & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & x & y \end{bmatrix}$, and $\hat{a}$ for $\begin{bmatrix} a_1 & a_2 & a_3 & a_4 & a_5 & a_6 \end{bmatrix}^T$.

Given the motion vector for each macroblock, we find the global parameter using the Least Squares (LS) estimation, that is to find a set of parameter $\hat{a}$ to minimize the error between the motion vectors estimated in (1) and the actual motion vectors obtained from the MPEG stream.

$$S(\hat{a}) = \sum_x \sum_y [(\hat{u}_{xy} - u_{xy})^2 + (\hat{v}_{xy} - v_{xy})^2]$$

where $\begin{bmatrix} \hat{u} & \hat{v} \end{bmatrix}^T$ is the estimated motion vector. To solve for $\hat{a}$, set the first derivative of $S(\hat{a})$ to 0, then we get

$$\begin{bmatrix} N & A & B \\ A & C & E \\ B & E & D \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \\ a_3 \end{bmatrix} = \begin{bmatrix} U_1 \\ U_2 \\ U_3 \end{bmatrix} \text{ and } \begin{bmatrix} N & A & B \\ A & C & E \\ B & E & D \end{bmatrix} \cdot \begin{bmatrix} a_4 \\ a_5 \\ a_6 \end{bmatrix} = \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix}$$

where,

$$N = \sum_x \sum_y 1,\ A = \sum_x \sum_y x,\ B = \sum_x \sum_y y,$$
$$C = \sum_x \sum_y x^2,\ D = \sum_x \sum_y y^2,\ E = \sum_x \sum_y x \cdot y,$$
$$U_1 = \sum_x \sum_y u_{xy},\ U_2 = \sum_x \sum_y u_{xy} \cdot x,\ U_3 = \sum_x \sum_y u_{xy} \cdot y,$$
$$V_1 = \sum_x \sum_y v_{xy},\ V_2 = \sum_x \sum_y v_{xy} \cdot x,\ V_3 = \sum_x \sum_y v_{xy} \cdot y.$$

All summations are over all valid macro-blocks whose motion vectors survive after the nonlinear noise reduction process. After the first LS estimation, motion vectors that have large distance from the estimated ones are filtered out before a second LS estimation. The estimation process is iterated several times to refine the accuracy.

Dominant motion can be estimated using clustering as follows:

For each B- or P-frame, obtain the forward motion vectors.

Assign each motion vector to one of a number (e.g. 4) of pre-defined classes.

Perform one round of global affine parameter estimation.

Assign the global affine parameter to the first class and assign zero to all other classes.

Iterate a number of times, e.g. 20, or until the residual error is stabilized: assigning each motion vector to the class that minimizes Euclidean distance and recalculating the 2-D affine parameters for each class using its member motion vectors.

CLAIMS

1. A method for including a watermark in a digital image, comprising:

obtaining digital data of a transformed representation of the image;

determining a transformed representation of the watermark for optimized visibility of the watermark in the image; and

superposing the transformed representation of the watermark on the transformed representation of the image.

2. The method in accordance with claim 1, wherein the transformed representation of the image is a compressed representation.

3. The method in accordance with claim 1, wherein the transformed representation of the image is a discrete cosine transformed representation.

4. The method in accordance with claim 1, wherein the image is one of a sequence of video images.

5. The method in accordance with claim 3, wherein the transformed representation includes motion compensation.

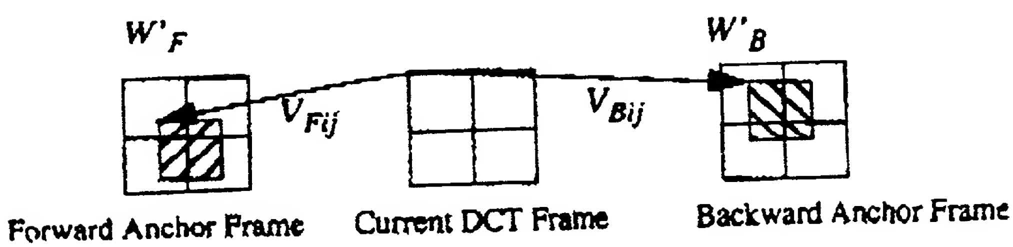
W'F
VFij
VBij
W'B
Forward Anchor Frame
Current DCT Frame
Backward Anchor Frame

Fig. 1

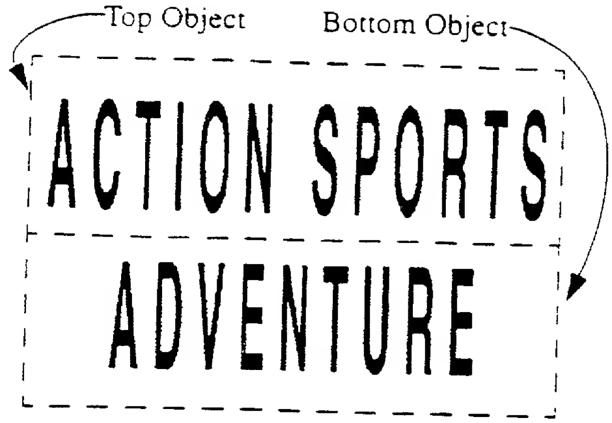

Fig. 2a

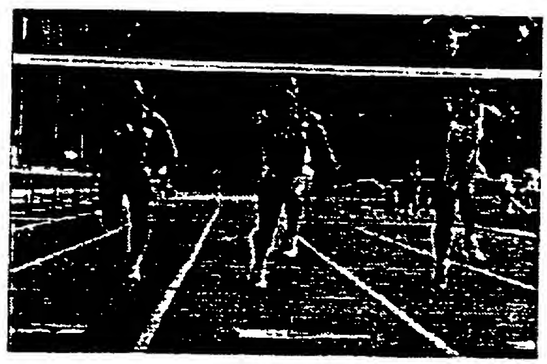

Fig. 2b

Fig. 2c

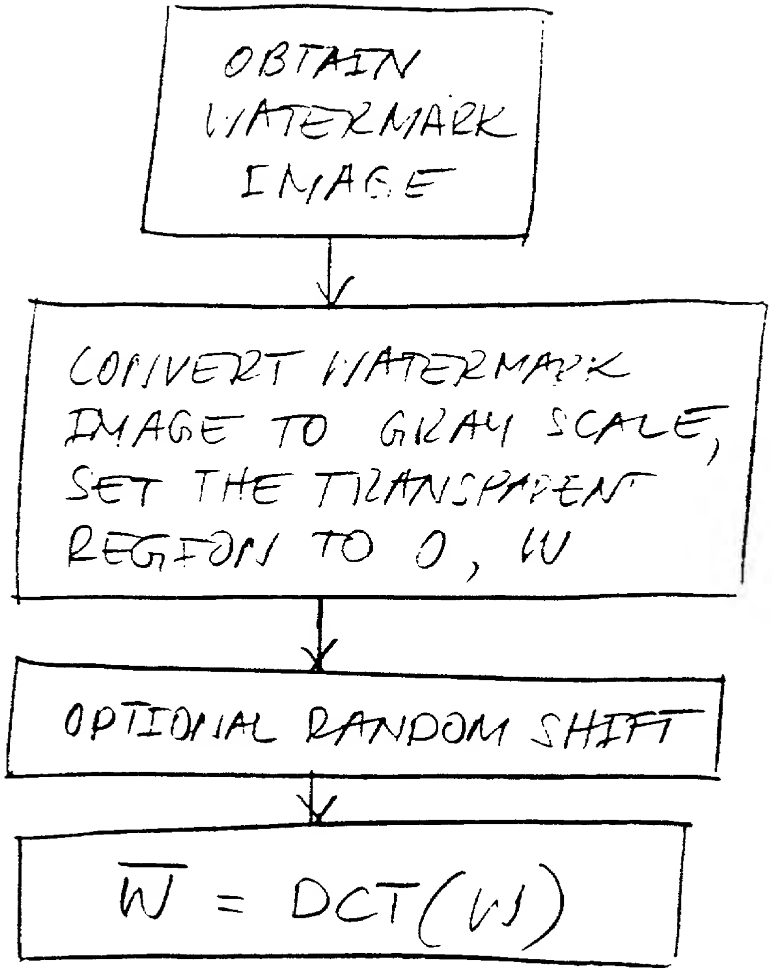
OBTAIN WATERMARK IMAGE
CONVERT WATERMARK IMAGE TO GRAY SCALE, SET THE TRANSPARENT REGION TO 0, W
OPTIONAL RANDOM SHIFT
$\overline{W}$ = DCT(W)

Fig. 3

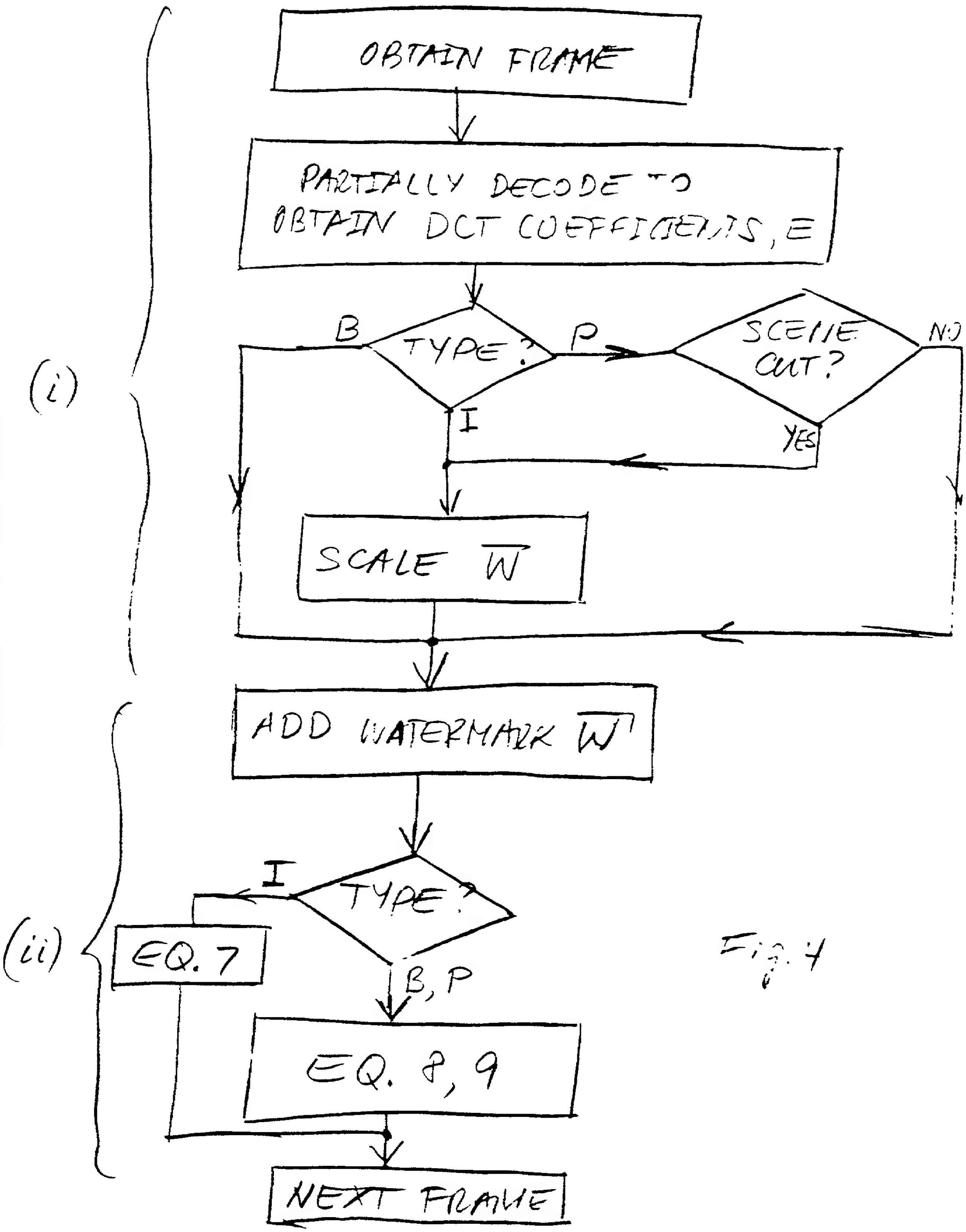
OBTAIN FRAME
PARTIALLY DECODE TO OBTAIN DCT COEFFICIENTS, E
B
TYPE?
P
SCENE CUT?
NO
I
YES
(i)
SCALE $\overline{W}$
ADD WATERMARK $\overline{W}'$
I
TYPE?
(ii)
EQ. 7
B, P
EQ. 8, 9
NEXT FRAME

Fig. 4

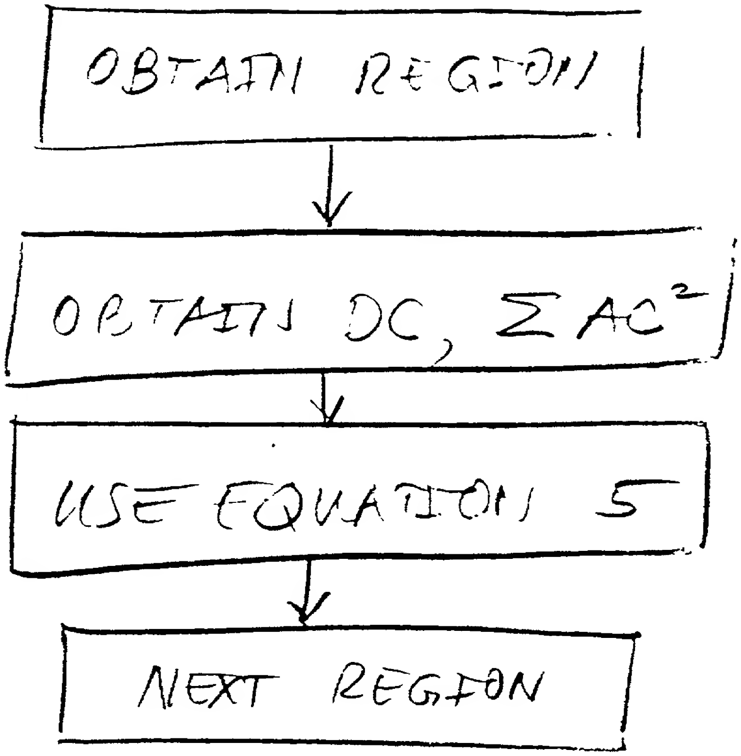
OBTAIN REGION
OBTAIN DC, ΣAC^2
USE EQUATION 5
NEXT REGION

Fig. 5

COMBINED DECLARATION AND POWER OF ATTORNEY

(Original, Design, National Stage of PCT, Divisional, Continuation or C-I-P Application)

As a below named inventor, I hereby declare that:
My residence, post office address and citizenship are as stated below next to my name; I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

WATERMARKING OF DIGITAL IMAGE DATA

This declaration is of the following type:

- [] original
- [] design
- [X] national stage of PCT.
- [] divisional
- [] continuation
- [] continuation-in-part (C-I-P)

the specification of which: *(complete (a), (b), or (c))*

(a) [ ] is attached hereto.
(b) [X] was filed on April 27, 2000 as Application Serial No. 09/530,308 and was amended on *(if applicable)*.
(c) [X] was described and claimed in PCT International Application No. PCT/US98/22790 filed on October 27, 1998 and was amended on *(if applicable)*.

Acknowledgement of Review of Papers and Duty of Candor

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of the subject matter claimed in this application in accordance with Title 37, Code of Federal Regulations § 1.56.

[ ] In compliance with this duty there is attached an information disclosure statement. 37 CFR 1.98.

Priority Claim

I hereby claim foreign priority benefits under Title 35, United States Code, § 119(a)-(d) of any foreign application(s) for patent or inventor's certificate or of any PCT International Application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT International Application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application on which priority is claimed

(complete (d) or (e))

(d) [ ] no such applications have been filed.
(e) [X] such applications have been filed as follows:

PRIOR FOREIGN/PCT APPLICATION(S) FILED WITHIN 12 MONTHS (6 MONTHS FOR DESIGN) PRIOR TO SAID APPLICATION				
COUNTRY	APPLICATION NO	DATE OF FILING (day, month, year)	DATE OF ISSUE (day, month, year)	PRIORITY CLAIMED UNDER 35 USC 119
				[ ] YES NO [ ]
				[ ] YES NO [ ]
				[ ] YES NO [ ]
ALL FOREIGN APPLICATION[S], IF ANY, FILED MORE THAN 12 MONTHS (6 MONTHS FOR DESIGN) PRIOR TO SAID APPLICATION				
United States	60/063,509	27/10/97		[X] YES NO [ ]
				[ ] YES NO [ ]
				[ ] YES NO [ ]

Claim for Benefit of Prior U.S. Provisional Application(s)

I hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below:

Provisional Application Number	Filing Date
60/063,509	October 27, 1997

Claim for Benefit of Earlier U.S./PCT Application(s) under 35 U.S.C. 120

(complete this part only if this is a divisional, continuation or C-I-P application)

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior application(s) in the manner provided by the first paragraph of Title 35, United States Code § 112, I acknowledge the duty to disclose information as defined in Title 37, Code of Federal Regulations, § 1.56 which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application:

(Application Serial No.) (Filing Date) (Status) (patented, pending, abandoned)

(Application Serial No) (Filing Date) (Status) (patented, pending, abandoned)

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Power of Attorney

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BAKER BOTTS L.L.P. 30 ROCKEFELLER PLAZA, NEW YORK, N.Y. 10112 CUSTOMER NUMBER: 21003	BAKER BOTTS L.L.P. (212) 705-5000

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section

1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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POST OFFICE ADDRESS	POST OFFICE ADDRESS	CITY	STATE or COUNTRY	ZIP CODE
DATE	SIGNATURE OF INVENTOR			